Brewster - "Treatise on Optics" 1853.
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two prisms or halves, A D C, C A B, so as to form a parallel plate, and by slightly turning round the prisms, he can easily find the position in which the two faces are perfectly parallel.

CHAP. LIII.

ON MICROSCOPES.

A MICROSCOPE is an optical instrument for magnifying and examining minute objects. Jansen and Drebell are supposed to have separately invented the single microscope, and Fontana and Galileo seem to have been the first who constructed the instrument in its compound form.

Single Microscope.

(230.) The single microscope is nothing more than a lens or sphere of any transparent substance, in the focus of which minute objects are placed. The rays which issue from each point of the objects are refracted by the lens into parallel rays, which, entering the eye placed immediately behind the lens, affords distinct vision of the object. The magnifying power of all such microscopes is equal to the distance at which we could examine the object most distinctly, divided by the focal length of the lens or sphere. If this distance is 5 inches, which it does not exceed in good eyes when they examine minute objects, then the magnifying power of each lens will be as follows: —

Focal length in inches.	Linear magnifying power.	Superficial magnifying power.
5	1	1
1	5	25
$\frac{1}{10}$	50	2500
$\frac{1}{100}$	500	250000

The *linear* magnifying power is the number of times an object is magnified in length, and the *superficial*

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magnifying power is the number of times that it is magnified in surface. If the object is a small square, then a lens of one inch focus will magnify the side of the square 5 times, and its area or surface 25 times.

The best single microscopes are minute lenses ground and polished on a concave tool; but as the perfect execution of these requires considerable skill, small spheres have been often constructed as a substitute. Dr. Hook executed these spheres in the following manner: Having drawn out a thin strip of window glass into threads by the flame of a lamp, he held one of these threads with its extremity in or near the flame, till it run into a globule. The globule was then cut off and placed above a small aperture, so that none of the rays which it transmitted passed through the part where it was joined to the thread of glass. He sometimes ground off the end of the thread, and polished that part of the sphere. Father di Torre of Naples improved these globules by placing them in small cavities in a piece of calcined tripoli, and remelting them with the blowpipe; the consequence of which was, that they assumed a perfectly spherical form. Mr. Butterfield executed similar spheres by taking upon the wetted point of a needle some fine pounded glass, and melting it by a spirit lamp into a globule. If the part next the needle was not melted, the globule was removed from the needle and taken up with the wetted needle on its round side, and again presented to the flame till it was a perfect sphere. M. Sivright, of Meggetland, has made lenses by putting pieces of glass in small round apertures between the 10th and 20th of an inch, made in platinum leaf. They were then melted by the blowpipe, so that the lenses were made and set at the same time.

Mr. Stephen Gray made globules for microscopes by inserting drops of water in small apertures. I have made them in the same way with oils and varnishes; but the finest of all single microscopes may be executed by forming minute plano-convex lenses upon or beneath glass either with plane, convex, or concave surfaces,

with different fluids, separate or combined. When the fluid is suspended below the glass, it takes a form approaching to the hyperbola, and its form varies according as the surface is plane, convex, or concave. A drop of fluid flattened by its weight, and resting upon plane glass, may be combined with a lens beneath and made hyperbolic by suspension. I have formed fluid doublets and triplets, either simple or achromatic, by the same means, and have succeeded in combining two immiscible fluids with a glass lens, namely, castor oil and treacle or pure honey. A hyperbolic figure may be formed by suspending within the fluid lens a convex lens of glass which weighs it down; and it may be made achromatic by suspending a concave lens. These various forms of fluid microscopes, or of fluid and solid lenses combined, may be made perfect by a simple method which I have adopted, of making the axes of the combined lenses perfectly coincident. I have made lenses of Canada Balsam of the 50th of an inch in focal length, and preserved it for many years.* I have also formed excellent microscopes by using the spherical crystalline lenses of minnows and other small fish, and taking care that the axis of the lens is the axis of vision, or that the observer looks through the lens in the same manner that the fish did.†

The most perfect single microscopes ever executed of solid substances are those made of the gems, such as *garnet*, *ruby*, *sapphire*, and *diamond*. The advantages of such lenses I first pointed out in my *Treatise on Philosophical Instruments*; and two lenses, one of ruby and another of garnet, were executed for me by Mr. Peter Hill, optician in Edinburgh. These lenses performed admirably, in consequence of their producing, with surfaces of inferior curvature, the same magnifying power as a glass lens; and the distinctness of the image was increased by their absorbing the extreme blue rays of the spectrum. Mr. Pritchard, of London, has carried

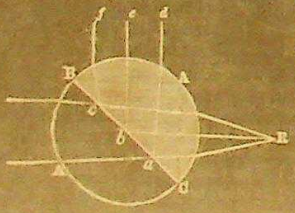
* See *Treatise on the Microscope*, p. .
† See *Edinburgh Journal of Science*, No. III. p. 98.

this branch of the art to the highest perfection, and has executed lenses of sapphire and diamond of great power and perfection of workmanship.

When the diamond can be procured perfectly homogeneous and free from double refraction, it may be wrought into a lens of the highest excellence; but the sapphire, which has double refraction, is less fitted for this purpose. Garnet is decidedly the best material for single lenses, as it has no double refraction, and may be procured, with a little attention, perfectly pure and homogeneous. I have now in my possession two garnet microscopes, executed by Mr. Adie, which far surpass every solid lens I have seen. Their focal length is between the 30th and the 50th of an inch. Mr. Veitch, of Inchbonny, has likewise executed some admirable garnet lenses out of a Greenland specimen of that mineral given to me by Sir Charles Giesecké. The late Mr. Blaikie, of Edinburgh, made some admirable lenses of diamond; garnet, sapphire, and at my request has executed both doublets and triplets with lenses made of gems, which are equal, if not superior, to any single microscope I have seen.

(231.) A single microscope, which occurred to me some years ago, is shown in *fig.* 212., and consists in a new method of *using a hemispherical lens so as to obtain from it twice the magnifying power which it possesses when used in the common way.* If A B C is a hemispherical lens, rays

Fig. 212.



issuing from my object, R, will be refracted at the first

surface A C, and, after total reflexion at the plane surface B C, will be again refracted at the second surface A B, and emerge in parallel directions *d e f*, exactly in the same manner as if they had not been reflected at the points *a*, *b*, *c*, but had passed through the other half B A′ C of a perfect sphere A B A′ C. The object at R will therefore be magnified in the same manner, and will be seen with the same distinctness as if it had been seen through a sphere of glass A B A′ C. We obtain, consequently, by this contrivance all the advantages of a spherical lens, which we believe never has been executed by grinding. The periscopic principle, which will presently be mentioned, may be communicated to this *catoptric* lens, as it may be called, by merely grinding off the angles B, C, or rough grinding an annular space on the plane surface B C. The confusion arising from the oblique refractions will thus be prevented, and the pencils from every part of the object will fall symmetrically upon the lens, and be symmetrically refracted.

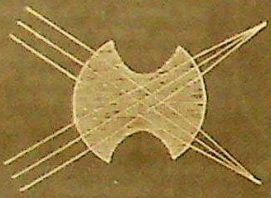
Before I had thought of this lens, Dr. Wollaston had proposed a method of improving lenses, which is shown in *fig.* 213. He introduced between two plano-convex lenses of equal size and radius a plane of metal with a circular aperture equal to $\frac{1}{4}$th of the focal length, and when the aperture was well centered, he found that the visible field was 20° in diameter. In this compound lens the oblique pencils pass, like the central ones, at right angles to the surface. If we compare this lens with the *catoptric* one above described, we shall see that the effect which is produced in the one case with two spherical and two plane surfaces, all ground separately, is produced in the other case by one spherical and one plane surface.

Fig. 213.

(232.) The idea of Dr. Wollaston may, however, be improved in other ways, by filling up the central aperture with a cement of the same refractive power as the lenses, or, what is far better, by taking a sphere of glass and

grinding away the equatorial parts, so as to limit the central aperture, as shown in *fig.* 214.*; a construction

Fig. 214.



which, when executed in garnet, and used in homogeneous light, we conceive to be the most perfect of all lenses, either for single microscopes, or for the object lenses of compound ones. A lens of this kind, whether the surfaces have the same or a different radius, may be called a *Concentric Lens*, and has valuable properties. An *Equivalent concentric* lens may be made by combining *two* plano-convex lenses with their plane sides separate but next one another, the lenses having different radii. The smaller lens may be either a hemisphere, or less or greater, and they may be so adjusted that the surface of the large lens may be in the focus of the combination, and consequently the place upon which the object is to be viewed.

Single microscopes may be made by combining *semi-lenses* or *quarters of lenses*, or any number of portions of a given lens.

* This lens, which goes by the name of the *Coddington lens*, was not invented by Mr. Coddington, nor was its invention ever claimed by him. It was invented by me long before 1820, and an account of it was published in the *Edinburgh Philosophical Journal*, April to July, 1820. I had many lenses of this kind (to which I gave the name of *Grooved spheres*), constructed by different artists, some of glass and some of garnet.

Mr. Coddington takes no notice of them in his *Treatise on Optics*, published in 1823, but he mentions them without any name in his *Treatise on the Reflexion and Refraction of Light*, published in 1829. Mr. Coddington had probably got one made by some London optician, who had ignorantly supposed it to be new, and presumed to give it a name to which it was not entitled.